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APPLICATION FOR UNITED STATES PATENT

Title: **REMOTE MAGNETIC ACTIVATION OF HEARING DEVICES**

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REMOTE MAGNETIC ACTIVATION OF HEARING DEVICES

Background of the Invention

a. Technical Field

The present invention relates generally to hearing devices, and more particularly to remotely controlled hearing devices which, when worn, are not easily accessible by the hearing impaired user.

b. Description of the Prior Art

Conventional hearing aids are typically equipped with one or more manually operated switches, such as an ON/OFF switch for activating or deactivating the device, or a control switch for adjusting the loudness or frequency response of the device. Improvements are continuously being made in the miniaturization of these controls in order to produce the smallest possible hearing device. Hearing devices are presently available, for example, that are sufficiently small to fit partially in the ear canal (In-The-Canal, or "ITC" devices) or entirely within the canal (Completely-In-the-Canal, or "CIC" devices), collectively referred to herein as “canal devices”.

Conventional switches used in hearing devices are electromechanical, with electrical settings that are dependent on mechanical position or movement of the switch. For example, U.S. Patent No. (USPN) 4,803,458 to Trine et al. discloses a hearing aid miniature switch which is integrated with a potentiometer. Hearing aid switches of the prior art, however, present several problems to manufacturers and users of canal devices. Among the

most serious problems presented to manufacturers, for example, is the difficulty of providing designs that allow sufficient space within the hearing device to incorporate a conventional switch along with other key components including the battery necessary to power the device. This problem is particularly frustrating for devices designed to be worn in small or narrow ear canals, but is manageable for the larger hearing devices such as Behind-The-Ear ("BTE") and In-The-Ear ("ITE") types. Therefore, conventional switches are usually limited to these larger hearing devices. Additionally, conventional switches are prone to malfunction and frequent repair because of the susceptibility of their mechanical parts to failure (see, for example, Valente, M., "Hearing Aids: Standards, Options, and Limitations", Thieme Medical Publishers, 1996, p. 239, hereinafter referred to as "Valente").

Among the problems presented to users of heretofore available canal devices are the inaccessibility of and difficulty to manipulate conventional switches, particularly for the geriatric population, which makes remote controlled hearing devices more suited to such users (Valente, p. 240).

Prior art remote control designs for hearing devices typically employ sound, ultrasonic, radio frequency (RF) or infrared (IR) signals for transmission to the device, examples of which are found in USPNs 4,845,755 to Busch et al., 4,957,432 to T. Pholm, 5,303,306 to Brillhart et al., and 4,918,736 to Bordewijk. Such designs typically require additional circuitry to decode the transmitted signal and provide control signals for its internal use, which mandates a need for additional space and power consumption in the device. Availability of space and power, however, are extremely limited in canal devices. Furthermore,

operation of buttons or switches typically provided on the remote control unit can present a daunting challenge to users with poor manual dexterity.

Remote control applications which employ reed switches activated by a magnetic field from a proximal magnet are well known, as typified by USPNs 3,967,224 to Seeley; 5,128,641, 5,233,322 and 5,293,523 to Posey; and 5,796,254 to Andrus. These patent disclosures describe various configurations of reed switches which are activated by a control magnetic material -- either a permanent magnet or a magnetically permeably material -- when placed in proximity to the controlled device. In general, these prior art reed switch remote control designs lack a latching mechanism, and therefore require the continued proximity of the control magnetic material to activate the controlled device. The switch reverts to its normal position immediately upon removal of the control magnetic material from the proximity area.

In prior art hearing aid applications employing a remotely activated reed switch, the switch is typically employed to trigger an input signal for a control circuit within the hearing device. For example, USPNs 5,359,321 to Rubic and 5,553,152 and 5,659,621 to Newton disclose reed switches activated remotely by a magnetic field introduced from a hand-held magnet. The reed switches of these prior art disclosures are connected to semiconductor logic or control circuitry and thus indirectly control or switch the parameters of the hearing device. It is well known in the art of semiconductors and circuit design that semiconductor switches can be bulky and require additional control circuitry.

A miniature latching reed switch is ideal for canal devices because no power or control circuitry is required to maintain a particular state. For example, a reed switch can be

used to turn off a hearing device by opening the battery circuit, and the off state is then maintained by the switch without consuming any energy from the battery. This is extremely important in long term device applications whereby battery longevity must be maximized.

A latching magnetic reed switch with two modes (positions) is disclosed in USPN 4,039,985 to Schlesinger, but the switch requires two latching magnets, one for each switch position. A more efficient latching type reed switch shown in **FIGS. 1** and **2**, manufactured by Hermetic Switch Inc. (model HSR-003DT), has a single magnet bar **M** mounted externally and perpendicular to the hermetically sealed tubular reed switch **R**. The ferromagnetic reeds **A** and **B** are attached to ferromagnetic lead wires $\mathbf{L_A}$ and $\mathbf{L_B}$. Because the latching magnet **M** is relatively large, the switch assembly (**SA**) is roughly twice the size of the reed switch **R** alone. The magnet may be made somewhat smaller by the selection of magnet material with higher intrinsic magnetic energy, but the air-gap (**AG**) between magnet **M** and either of the reeds (**A** and **B**) dictates the need for a substantial magnet size to produce the required latching force.

For canal hearing devices, the prior art latching reed switches referred to above are impractical due to size and configuration considerations. As illustrated in **FIG. 3**, the human ear canal cavity **30** is generally narrow and elongate. Conventional non-latching miniature reed switches (**R**) are also narrow and elongate making them ideal for concentric longitudinal placement within the ear canal as shown, but the prior art methods of incorporating one or more reed switches **R** and latching magnets **M** (shown with dotted perimeter) mandate a prohibitively large switch assembly (**SA**), as indicated in **FIG. 3**. The significance of this size

limitation is best understood when considering the need to incorporate other critical components (not shown) within a canal hearing device **70**, such as a battery, microphone, amplifier circuitry, speaker, and so forth.

It is a principal objective of the present invention to provide an extremely space efficient latching reed switch assembly for use within a miniature hearing device, particularly a canal device. It is also an objective of the invention to provide an easy to use remote control method, particularly for persons of poor manual dexterity. Other objectives include reliable operation, inexpensive design and elimination of standby electrical power.

Summary of the Invention

The present invention provides a magnetic switch assembly for hearing devices adapted for remote activation by the user. The magnetic switch assembly is highly miniaturized with a self-contained latching mechanism. User activation is performed by placing a hand-held magnet in proximity to the hearing device. The magnetically latchable switch eliminates conventional miniature electromechanical switches, which are manually controlled and thus not practical for inaccessible hearing devices or for persons of poor dexterity. It also eliminates conventional wireless remote control methods, which require additional circuitry and electrical power.

The switch assembly according to a presently preferred embodiment of the invention comprises a miniature reed switch and a miniature latching magnet affixed directly to one of the reeds or to an electrical lead wire associated with a reed. Direct attachment

eliminates air gaps between the latching magnet and a reed, thus enabling latching with an extremely small magnet. The magnet, with its ultra-small size, increases the dimensions of the switch assembly by only a negligible amount.

In the "open" position of the switch assembly, in the absence of an external magnetic field (i.e., unaided), the latching magnet generates a weak attraction force by virtue of its limited magnetic field strength which is insufficient to overcome the air gap between the reeds themselves, i.e., to pull together and close the contacts of the two reeds. However, with the application of an external "on" magnetic field (i.e., suitable proximity, polarity and field strength) from an external control magnet wielded by the wearer (i.e., the user) and placed close to the hearing device, the attraction force becomes sufficient to close the contacts. After assuming a "closed" position, the reed contacts remain closed (latched) under the influence of the latching magnet, even after the removal of the external control magnet. Similarly, the switch contacts can be latchably opened by the application of an external "off" magnetic field from an external control magnet sufficient to overcome the latching force of the latching magnet. Preferably, the control magnet is a hand-held bar with opposite magnetic polarities at its ends, for switching according to the polarity of the end placed proximate to the hearing device.

In the preferred embodiment of the invention, the latching magnet is placed directly on a ferromagnetic lead wire associated with a first reed of a tubular reed switch positioned horizontally in the ear canal. A second ferromagnetic lead wire, associated with a second reed, is positioned laterally to face an activating magnet placed in close proximity to the

aperture of the ear canal by the wearer.

The miniature tubular reed switch assembly of the present invention minimally impacts the overall size of the associated hearing device. The sealed switch assembly is more reliable and more conveniently activated than conventional electromechanical switches. It is also more energy efficient and cost effective than prior art wireless switches.

Brief Description of the Drawings.

The above and still further objectives, features, aspects and attendant advantages of the present invention will become apparent from the following detailed description of a preferred embodiment and method of manufacture thereof constituting the best mode presently contemplated of practicing the invention, when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a fragmentary side view of a latching reed switch assembly of the prior art, discussed above, in which a latching magnet is positioned along the length of the reed switch with an air-gap therebetween;

FIG. 2 is a cross-sectional view of the latching reed switch assembly of **FIG. 1**, discussed above;

FIG. 3 is a transparent partial side view of a prior art reed switch assembly in a canal hearing device, discussed above, positioned within a human ear canal;

FIG. 4 is a side view of a preferred embodiment of a switch of the present invention, in the open position showing a latching magnet externally positioned and directly on

the ferromagnetic lead wire;

FIG. 5 is a side view of the switch embodiment of **FIG. 4** in the closed position, showing the control magnet in proximity to the switch;

FIG. 6 is a side view of the switch embodiment of **FIG. 4** in the open position, showing magnetic flux lines within the reed switch and from a control magnet placed in proximity thereto;

FIG. 7 is a side view of an alternative embodiment of the reed switch of the invention, with latching magnet internal to the casing and directly affixed to one of the reeds;

FIG. 8 is a side view of another embodiment of the reed switch, in which a magnet is adhesively wedged between the two lead wires of the reeds of the switch;

FIG. 9 is a schematic representation of the latching reed switch assembly of the invention, used as a power switch (ON/OFF) in a hearing device;

FIG. 10 is a schematic representation of the latching reed switch assembly of the invention, used as a volume control switch in a hearing device;

FIG. 11 is a side view of a dual switch configuration showing individual switch action according to the proximity of a control magnet;

FIG. 12 is a side view of the reed switch assembly of the invention in a canal hearing device, with a control magnet in proximity thereto; and

FIG. 13 is a side view of the reed switch assembly of the invention in an implanted hearing device, with a control magnet inserted in the ear canal in close proximity to the hearing device.

Detailed Description of the Presently Preferred Embodiments and Methods of the Invention

The present invention provides a hearing device that utilizes an ultra miniature switch assembly with unique latching characteristics, remotely activated by a magnet wielded by the wearer. The hearing device is of the canal or implanted device type, so a conventional electromechanical or other switch would not be easily accessible by the wearer. The switch assembly of the invention consists of a miniature reed switch assembly having a pair of reeds within the assembly and a pair of connecting lead wires, and in which a miniature permanent magnet is directly attached either to one of the reeds or to the lead wire associated with the respective reed.

In a preferred embodiment, shown in **FIG. 4**, the magnetic reed switch assembly **50** is tubular and comprises a hermetically sealing glass casing **51** containing a first reed **52** and a relatively more mobile second reed **53**. The reeds are made of flexible ferromagnetic material and thus move in response to a magnetic field. The first and second reeds are attached to connecting lead wires **54** and **55**, respectively, which are connected to appropriate points of an electrical circuit. The lead wires are preferably also composed of ferromagnetic material, such as nickel-iron alloy, to enhance the sensitivity and response of the connected reeds to a magnetic field applied proximal to either of the lead wires. In the absence of a magnetic field of sufficient strength, the reeds form an air-gap **57** representing an open contact in the normal position. The normal orientation and mechanical properties of the reeds cause the switch to remain in the "open" position (i.e., an open circuit condition, where the electrical circuit in which the reed switch is connected remains non-conductive as long as that condition exists).

However, when one of the reeds is exposed to a sufficient magnetic field **61** from an external magnet **60** (**FIG. 5**), the exposed reed becomes magnetized thus attracting the other reed until a closure of the reed contacts occur. This condition represents the "closed" position of the switch (i.e., a closed circuit condition, where the electrical circuit is then conductive) as shown in **FIG. 5**, in which second reed **53** makes contact with first reed **52** and air-gap **57** (**FIG. 4**) is eliminated.

Preferably, the miniature latching magnet **56** is mounted directly to the ferromagnetic first lead wire **54**. An adhesive **59** is applied at the edge of the magnet-lead junction to hold the magnet to the lead wire **54**. The latching magnet **56** produces a magnetic field and, thereby, a force of attraction between reeds **52** and **53**. This attraction force alone, however, is intentionally insufficient to close the reed contacts, and hence, the switch remains latched in the "open" position. However, in the presence of a magnetic field **61** produced by a proximate control magnet **60** of appropriate orientation and polarity (**60'**), the attraction force between the reeds will increase, causing a closure of the contacts and the electrical circuit associated with lead wires **54** and **55**. The "closed" condition, shown in **FIG. 5**, occurs when the control magnet **60** is moved to position **60'** in the direction of arrow **62** and towards second lead wire **55**. In the closed position, the air-gap **57** (**FIG. 4**) between the reeds is eliminated which increases the flux density and the attraction force between the contact reeds. The elimination of the air-gap **57** in the closed position and the magnetic field strength of the latching magnet **56** enables the magnet to maintain closure of the switch even after the removal of the external control magnet **60**. Reversing the switch to the normal open position is

achieved simply by reversing the polarity of the control magnet **60** and placing it similarly within proximity of second lead wire **55** (condition not shown) to overcome the latching force of the latching magnet **56**, whereupon the reed contacts will undergo separation from one another.

FIG. 6 shows the effect of magnetic flux lines **69** from a control magnet **60** on the reed switch assembly **50**. Flux lines within the reed switch assembly (shown by arrow **90**) are partially caused by latching magnet **56** and are enhanced to cause closure by flux lines **69** from control magnet **60**. The latching magnet **56** is magnetically polarized across (**N** and **S** as shown) in order to cause a flux circuit **90** within the reed switch assembly as shown.

The magnet type, size, shape, orientation with respect to the reed switch, and other characteristics are designed such that a latching closure force only occurs upon the substantial reduction of the air-gap **57** between the reeds. Once the reed contacts are opened by an external magnetic force and an air-gap **57** develops in between, the attraction force caused by the latching magnet alone is not sufficient to overcome the mechanical bias force of the reeds towards the open position.

The significance of the present invention in terms of size and weight reduction and simplicity of use will be demonstrated presently herein with reference to Examples 1 and 2 below.

The latching magnet **56** is preferably composed of rare-earth material such as Neodymium Iron Boron (NdFeB) or Samarium Cobalt (SmCo). These magnets are known for their high energy properties, and are typically coated with nickel, gold, aluminum, or other

material to prevent corrosion and deterioration of magnetic energy.

In another embodiment of the invention, shown in **FIG. 7**, the latching magnet **56** is attached to a first reed **52** within casing **51**. This configuration provides several advantages including further size reduction of the magnet **56** due to its direct contact with the reed and elimination of coating requirement due to the hermetic sealing effect.

In yet another embodiment, shown in **FIG. 8**, the latching magnet **56** is wedged in between the two ferromagnetic lead wires with thin layers of adhesive **59** (top and bottom) holding the magnet in place.

Regardless of the configuration or embodiment of the present invention, the spacing between the latching magnet **56** and the underlying ferromagnetic contact must be essentially eliminated in order to achieve the improved efficiency. However, a miniscule spacing, not exceeding approximately 0.2 mm, is permissible since it produces negligible adverse effect on the performance of the switch assembly. This spacing may be caused by a thin layer of magnet coating (not shown) or a layer of adhesive as shown in **FIG. 8**.

An ideal application of the present invention is in remote power switching (ON/OFF) of inaccessible hearing devices. A simplified schematic of this example application is shown in **FIG. 9**. The reed switch assembly **50** connects and disconnects power terminal **78** from battery **71** to any active electrical or electroacoustic component such as amplifier **73**, microphone **72** or receiver (speaker) **74**. Once the switch assembly is remotely turned off, the current drain from the battery is completely shut off and no stand-by current is consumed while the hearing device is in the off position. This energy efficient feature of the present invention

is critical for long-term-use applications of canal or implant hearing devices.

Another application of the present invention is in device adjustment such as volume, frequency response or other control or operating parameter. A simplified schematic of a volume control switch, for example, is shown in **FIG. 10**. The reed switch assembly **50** inserts, on demand by the user, a feedback resistance **75** in the feedback pathway of amplifier **73** (input impedance not shown, for the sake of simplicity). This reduces the amplification, thus altering the volume setting of the hearing device **70**.

Two or more switches of the present invention may be combined in the same hearing device to control two or more settings -- for example, power and volume settings. **FIG. 11** shows a dual switch assembly with a single shared latching magnet **M**. The reed switches **R1** and **R2** are configured with lead wires **L1** and **L2** extended to different lengths as shown. Lead wire **L1** being closer to the control magnet **60** causes switch **R1** to be activated prior to switch **R2**. This provides a position sensitive control for each of the two settings. For example, when the north pole of the control magnet **62** reaches position **N1**, **R1** switch responds and activates (turns ON) the hearing device. As the control magnet **60** further approaches the dual switch, **R2** switch is subsequently activated and an increase in the volume (or change in frequency response, depending on switch application) occurs.

FIG. 12 shows an application of the present invention in a canal hearing device. The hearing device **70** is fully inserted in the ear canal **30** terminating medially by the tympanic membrane **32** (eardrum). The switch assembly **50** is part of a canal device **70** with lead wire **55** laterally positioned facing the magnetic field **61** emanating from a control magnet **60**. The

bar-shaped control magnet **60** has two magnets **65** and **66** with opposing magnetic polarities (**N** and **S**) on each end. The control magnet may be equally effective with a single bar magnet.

Stopper flanges, **67** and **68**, are optionally placed on each end of the control magnet **64** to prevent it from entering the ear canal and possibly touching or pushing the canal device **70**.

The control magnet of the present invention preferably incorporates permanent magnets (e.g., magnetic poles of opposite polarity at opposite ends of a bar magnet). However, a magnetic field may be generated by other means known in the art such as by an electromagnet (not shown) comprising a coil, a battery and a switch.

The latching reed switch assembly of the present invention is suitable for any body-worn hearing or audio device that is not readily accessible by the wearer. In implant applications, as shown in **FIG. 13** for example, a hearing device **80** is surgically implanted with a vibrating transducer **81** placed on a vibratory structure (not shown) of the middle or inner ear. The implanted hearing device **80** is remotely activated by a control magnet **64** placed in the ear canal by the user.

Two examples of reed switch assemblies fabricated according to the invention will now be described.

<u>Example 1</u>:

A latching reed switch assembly according to a preferred configuration of the present invention, shown in **FIGS. 4-6**, was constructed and compared to the prior art switch configuration shown in **FIG. 1**. The prior art latching reed switch assembly was based on

micro-miniature reed switch model HRS-003DT manufactured by Hermetic Switch, Inc. of Chickasha, Oklahoma. The prior art switch assembly included a latching magnet rod (**M**) constructed of Alnico material and positioned along the length of the tubular reed switch shown in **FIG. 1**. The magnet **M** was approximately 4.1 mm long and 1.8 mm in diameter, with a volume of approximately 10.4 mm^3. The weight of the magnet was measured to be approximately 74 mg. The reed switch was approximately 5 mm long and 1.25 mm in diameter, with a volume of approximately 6.1 mm^3. The reed switch weighed approximately 17 mg with a total of 11 mm of the lead wire attached. The combined volume and weight of the prior art reed switch assembly were approximately 16.5 mm^3 and 91 mg, respectively. The cross sectional long diameter ($\mathbf{D_L}$, **FIG. 2**) of the assembly was 3.05 mm.

The embodiment of the present invention shown in **FIGS. 4-6** was fabricated using the same reed switch (model HSR-003DT) but with an ultra miniature magnet **56** placed directly on lead wire **54**. The magnet, weighing approximately 1.7 mg, was made of Neodymium Iron Boron (NdFeB), a rare-earth magnet which, as noted above, is known for its high magnetic energy (energy product). The miniature magnet was shaped as a thin slab approximately 1 mm L x 0.62 mm W and 0.38 mm H with volume of 0.24 mm^3 (vs. 10.4 mm^3 in prior art designs). The combined volume and weight of the example magnet were approximately 6.3 mm^3 and 18.7 mg, respectively. Since the latching magnet **56** is placed on lead wire **54** and its height is only 0.38 mm, the cross sectional diameter of the switch assembly of the present invention is essentially that of the reed switch casing **51**. The magnet was aluminum plated to prevent corrosion of the magnetic material. The distant end **57** of the

second lead wire **55** was bent and brought close facing the top of magnet **56** and creating an external gap **58** as shown in **FIGS. 4** and **6**. Minimizing the external gap **58** **(FIG. 5)** increases the magnetic flux density, thus producing a latching force with even a smaller latching magnet **56**.

The correct position of the latching magnet **56** on the lead wire was empirically determined by first placing the latching magnet approximately 5 mm way from edge of the casing **51**. The latching magnet **56** was then gradually glided on the lead wire towards the first reed **52** until the reed contacts closed. The latching magnet was then moved away approximately 1/3 mm. This ensured a magnetic attraction between the reeds just below the threshold of closure in the open position. The latching magnet **56** was then attached to the lead wire **54** by a careful application of an adhesive (Loctite 4014). The latching magnet position was approximately 1 mm away from the glass casing **51**. The reed switch assembly was then potted with silicone rubber for environmental and handling protection.

A summary comparison between the prior art switch assembly and the switch assembly of the present invention is shown in Table 1 below.

Table 1

	Prior Art Switch (Fig. 1)	**Present Invention Switch (Fig. 5)**
Assembly Volume	16.5 mm	6.3 mm
Assembly Weight	91 mg	18.7 mg
Magnet Weight	74 mg	1.7 mg
Cross Section Long Diameter	3.05 mm	1.25 mm

As indicated in Table 1 above, the magnetic switch assembly of the present invention is considerably more efficient than prior art switches in terms of weight, size and configuration for incorporation into a miniature canal hearing device.

Example 2:

A control magnet was fabricated to control the latching reed switch assembly described in Example 1 above. The control magnet **60** shown in **FIG. 12** was in the shape of a cylindrical rod having a length of 4.3 cm and a diameter of 5.3 mm. The body **64** of the rod was made of plastic and is attached to a pair of identical disk magnets **65** and **66**. The two magnets were polarized across the length of the rod and were oriented to have opposing magnetic polarity as shown in **FIG. 6**. The disk magnets were made of NdFeB material sold by Radio Shack (model no. 64-1895). Each disk magnet was approximately 4.3 mm in diameter and 1.5 mm in height.

The control magnet also had two flanged stoppers (**67** and **68**), designed to prevent the control magnet from entering the ear canal and accidentally pushing or touching any of the components of the canal hearing device **70**. Each stopper was made of polyurethane foam material but, alternatively, may be composed of any other suitable material such as plastic, silicone or silicone rubber.

The function of the control magnet of the above example was tested in conjunction with the latching reed switch assembly described in Example 1. It was found that effective and reliable latching occurred when either end of control magnet (**65** or **66**) was

positioned approximately 15 mm from the switch assembly **50**. This distance is considered ideal since it places the control magnet within the vicinity of the canal aperture **31** as shown in **FIG. 12**.

From the foregoing description, it will be understood that the invention provides a hearing device adapted to be positioned in the ear canal of a wearer (or alternatively, to be surgically implanted adjacent to the ear canal), which includes electrical circuit means for receiving and processing incoming signals representative of audio signals and converting them to an output for exciting a vibratory structure of the ear of the wearer such as the tympanic membrane, so as to reproduce the processed audio signals therefrom; a magnetically controlled latchable reed switch assembly for controlling at least one of activation and deactivation of the hearing device, or an operating parameter such as volume control or frequency response. The reed switch assembly includes a reed switch including first and second reeds providing electrical contacts spaced apart by an air gap, respective lead wires electrically connected to the first and second reeds and to the electrical circuit means, and a latching magnet directly affixed to either the first reed or to the lead wire associated with the first reed. The latching magnet has a magnetic field of sufficient strength to maintain the first and second reeds together in electrical contact after the air gap is eliminated by an externally applied magnetic field of suitable magnitude, polarity and proximity, but of insufficient strength to bring the first and second reeds together in electrical contact while the air gap exists.

The hearing device of the invention may have the latching magnet directly affixed to one of the reeds, but in the preferred embodiment each of the lead wires is

ferromagnetic and the latching magnet is directly affixed to one of the ferromagnetic lead wires. Alternatively, the latching magnet may be wedged between the ferromagnetic lead wires. The reed switch assembly would typically be a power switch for activation and deactivation of the hearing device, but alternatively or additionally, it may be connected so as to control an operating parameter of the device such as loudness of the output signal that provides the vibratory excitation to enhance the wearer's hearing, or the frequency response of the hearing device.

Although a presently contemplated best mode of practicing the invention has been described herein, it will be recognized by those skilled in the art to which the invention pertains from a consideration of the foregoing description of a presently preferred embodiment, that variations and modifications of this exemplary embodiment and method may be made without departing from the true spirit and scope of the invention. Thus, the foregoing embodiments of the invention should not be viewed as exhaustive or as limiting the invention to the precise configurations disclosed. Rather, it is intended that the invention shall be limited only by the appended claims and the rules and principles of applicable law.